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An examination of brain dominance and learning styles of pre-service mathematics teachers

Kemal Özgen[a]*, Berna Tataroğlu[a], Hüseyin Alkan[a]

[a] Buca Education Faculty, Dokuz Eylül University, İzmir, 35150, Turkey

Abstract

The aim of this study is to determine the brain dominance and learning style profiles of pre-service mathematics teachers and establish the relationships between them. The study, which was conducted with survey model, was carried out with the participation of 273 pre-service mathematics teachers. "Brain Dominance Analysis" and "Learning Style Inventory" were used as data collection tools in the study. As a result of the analysis of data, it was determined that pre-service mathematics teachers usually preferred "converger" and "assimilator" learning styles. The analysis revealed that "C" and "D" brain quadrants of pre-service teachers were dominant. Statistically significant differences were found in A, B, C quadrants of brain dominance analysis scores according to learning styles. In all of the learning styles, C quadrant received the highest scores, while A quadrant received lowest. In the study, a high-level correlation was not found between learning style dimensions and dominant brain quadrants.

Keywords: Pre-service mathematics teachers, learning style, brain dominance

1. Introduction

It is assumed that learning involves a lot of complex components such as environmental, emotional, sociological, physiological, psychological ones (Dunn, 1983). During different stages of learning process, differences are observed between individuals and these are referred as individual differences in education. The brain dominance and learning style preferences of individuals are also regarded among individual differences. Knowing how learning takes place; and mental activities that are performed to reflect this on learning environment during learning process are important for brain hemisphere preferences and learning styles. For this reason, studies about brain hemispheres and learning styles continue to draw interest both in past and today.

The studies about split brain show that different types of information are processed in left and right brain hemispheres and the functions of these two hemispheres are different (Solso, Maclin & Maclin, 2007: 80). According to studies, left hemisphere exhibits a more analytic approach, while right hemisphere displays holistic and spatial approach. Each hemispheres have special mental abilities. The left hemisphere is analytical, abstract, verbal, digital, logical, sequential, and rational, while the right hemisphere is holistic, concrete, non-verbal, visual-spatial, intuitive, simultaneous and analogical (McCarthy, Germain & Lippitt, 2006). Both hemispheres are in interaction with each other under normal circumstances. However, each has different basic functions. Herrmann

* Kemal Özgen. Tel.: +90-232-4204882
E-mail address: kemal.ozgen@deu.edu.tr

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states that separating the human brain into two parts as left / right brain is insufficient in terms of identifying the differences (Herrmann, 2003).

In Herrmann's four quadrant brain model, which was formed in 1995, the upper left quadrant of the brain is shown with letter A, while others are shown in B, C and D counter clockwise. In the metaphorical Whole Brain Model of Herrmann, these four quadrants are right and left cerebral halves (upper right and left quadrants) and right and left limbic halves (lower right and left quadrants). The combination of two left quadrant results in left-brain thinking dominance, while the combination of two right quadrants results in right-brain thinking dominance. In this model (Herrmann, 2003: 18-19): A quadrant is analyzer; thinking logically and carries out numerical operations; B quadrant is organizer; plans the approaches, organizes the events and evaluates them in detail; C quadrant is individualizer; intuitive, explanatory and deals with human relationships; while D quadrant imaginative; conceptualizes events and provides an active imagination and wide-scoped thinking.

Adopting the findings about mental activities of individuals to education, Herrmann uses the term "brain dominance" in order to emphasize the fact that humans use a certain part of their brain more often than other parts. The dominant brain concept, similar to the natural dominance concept between the double-structured parts of body (ie. right-left hand), is applied evenly to the brain and forms the fundamental point of dominant brain theory. For the examination of this model, individual's preference rates for each of the four different thinking types, their interest or distance to other types are highlighted (Herrmann, 2003: 32-33). This model exhibits the mental preferences of the individuals, but it doesn't show their abilities or competence. It creates a strong connection between skills and preferences that affect each other (Herrmann, 2003: 45).

On the other hand, two people who have exactly the same mental profile may not always have the same mental preferences. Since there would be different priority order for each quadrant, these two people may exhibit mental preference differences (Özden, 2009: 99). Herrmann emphasizes that humans are born with certain mental abilities, that everybody has strong and weak sides and the tendency to use the dominant brain hemisphere develops over time. He also states that the brain learns as a whole and using brain hemisphere together has a vital importance in learning.

Discussions about brain hemispheres reveal the fact that there are differences between individual learning styles (Caine & Caine, 2002: 37). Different models, approaches and inventories have been developed depending as a result of findings of brain studies. For example, McCarthy identified the 4MAT learning model by taking the brain hemispheres into account (McCarthy, Germain & Lippitt, 2006). In the conducted studies, it is sometimes seen that the concepts of learning style, cognitive style and modes of thinking are used interchangeably. However, researchers such as Campbell (1991), Keefe (1979), Cano-Garcia & Hughes (2004) and Leng & Hoo (1997) point out that these concepts are different and they can't be used as synonyms. Also in this presented study, learning style is assumed to be a different concept from brain hemisphere preferences. In reality, learning style is the sum of all cognitive, affective and psychological elements that determine how the individual perceives the learning environment, how they interact with the environment and how they react to this environment (Keefe, 1979). Today, there are a lot of learning style inventories and classifications of them. Each of these classifications deals with a different aspect of learning process, which is explained in "How do we learn?" sub-heading.

Kolb's learning style, which is one of the learning style models, is based upon the Experimental Learning Theory of Kolb. This theory assumes that learning takes place through the transformation of knowledge and experience. It is claimed that during the learning process, there are two separate dimensions; namely, perception / comprehension and processing / transformation (Kolb, 1984: 41). While these two dimensions are independent from each other, they also support each other. In this regard, there are four basic categories in Kolb's learning style model: Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC) and Active Experimentation (AE). These are, respectively, learning by "*feeling*" in concrete experience, learning by "*observing*" in reflective observation, learning by "*thinking*" in abstract conceptualization and learning by "*doing*" in active experimentation. According to Experimental Learning Theory, learning is a cycle. For an individual, one of these four categories gains priority from time to time and it is inevitable to go through this cycle indefinite number of times during a learning experience. In this model, students are sorted according to their preferences about concrete experience or abstract conceptualization (how they receive and grasp the knowledge) and active experimentation or reflective observation (how they transform and internalize the knowledge) (Felder, 1996; Kolb & Kolb, 2005).

One element doesn't offer the dominant learning style of an individual on its own. Learning style of each individual is identified as the component of four elements. The combined scores reveal the different preferences of individual from abstract to concrete and from active to reflective. These two groups of learning type create the basis for Kolb's two dimensional learning styles. As a result of combination of these four elements in two different dimensions, it is determined what dominant learning style individuals prefer out of four. These are; *diverger, assimilator, converger* and *accommodator* learning styles (Kolb & Kolb, 2005).

The fact that education system appreciates a certain thinking type and neglects the others results in nonuse of a capacity that exists in humans (Özden, 2009: 100). Schools only carry out their responsibilities if they can appreciate the student's capacities and their needs to evaluate the life and event with different thinking manners. In order to do this, teachers should have knowledge about the structure of brain, how the learning occurs and learning preferences of students and they should adapt the learning strategies about the efficient use of both hemispheres to teaching plans and learning environment.

There is also a left-right brain theory that deals with the development of learning in order to explain the variety of learning styles in students (Kitchnes, Barber & Barber, 1991). According to Guild (1997), each of the education theories that are based on multiple intelligence, learning style and brain encourages individualization in education by relating to whole life of students during the learning in classroom. For example, in her 4MAT learning system model, which is based on the learning styles of the students, McCarthy conducts the learning cycle by taking the brain hemisphere preferences of students into consideration (McCarthy, Germain & Lippitt, 2006).

One should be familiar with the brain dominance and learning styles of students in order to understand the mathematics learning process better, and attain individualization in education by considering the individual differences. This knowledge may be helpful for teachers in encouraging the students during mathematics learning process, in relating the learners with teaching techniques and obtaining a more flexible and efficient education (Bielefeldt, 2006). Knowing the brain dominance and learning styles of pre-service mathematics teachers and, in this direction, having them go through learning processes which are suitable for their individual differences might make it easier for them to follow the same attitude and approach during their careers as teachers. It was determined that there are studies which investigate the brain dominance and learning styles together in the literature (Ali & Kor, 2007; Bielefeldt, 2006; Kırkgöz & Doğanay, 2003; Leng et al., 1998). There are also studies in mathematics education literature which investigate the brain dominance and learning styles of pre-service teachers (Ali & Kor, 2007; Elçi, 2008; Fer, 2003; Küçükkaragöz, et al., 2009; Orhun, 2007; Peker, Mirasyedioğlu & Aydın, 2004; Peker, 2009; Seng & Yeo, 2000). However, the number of studies that investigate the brain hemisphere preferences and learning styles of pre-service teachers together and try to interpret the relationship between them is limited.

The aim of this study is to determine the brain dominance and learning style profiles of pre-service mathematics teachers and establish the relationships between them. In order to achieve this, the answers to the following sub-problems shall be sought after by using the data that is obtained from pre-service mathematics teachers:

1. What are the learning style profiles of pre-service mathematics teachers?
2. What are the brain dominance profiles of pre-service mathematics teachers?
3. What are the brain dominance preferences of pre-service mathematics teachers in terms of their learning styles?
4. Does brain dominance of pre-service mathematics teachers significantly differ according to their learning styles?
5. Is there a significant relation between the brain dominance and the dimensions of learning styles of pre-service mathematics teachers?

2. Method

This study was carried out with a descriptive survey model. Survey models are research approaches that aim to describe an event that exists or existed in the past accurately. The event, individual or object that is discussed in the study is identified in its own conditions accurately (Karasar, 2005: 77). For that, it was deemed to be appropriate for the research of brain dominance and learning style profiles of pre-service mathematics teachers.

2.1. Participants

The study was conducted with 273 pre-service mathematics teachers who were students in Department of Secondary Mathematics Teacher Education in a state university. The students in 1st, 2nd, 3rd, 4th and 5th grade participated in the study with the thought that it shall provide a high level contribution in identifying the brain dominance and learning style profiles of pre-service teachers. Of the pre-service mathematics teachers that participated in the study, 120 were male (44%) while 153 were female (56%). Of the pre-service teachers; 70 were 1st grade (25,6%), 58 were 2nd grade (21,2%), 50 were 3rd grade (18,3%), 59 were 4th grade (21,6%) and 36 were 5th grade (13,2%).

2.2. Instruments

Data on brain dominance and learning styles of pre-service mathematics teachers were compiled through two instruments. "Brain Dominance Analysis" instrument which is the version of Herrmann Brain Dominance Instrument adapted to Turkish by Özden (2009) was applied in order to determine brain dominances of the pre-service teachers. The instrument consists of 6 subsections and a total of 24 items (4 items for all quadrants in the four-quadrant brain model in each subsection). The items are rated on a five-point rating scale including "Strongly disagree", "Disagree", "Not sure", "Agree" and "Strongly agree". Cronbach alpha reliability coefficient, which was determined as a result of applying the brain dominance analysis instrument to the study group, was calculated as 0,71 for the whole inventory. *"The Learning Style Inventory"* developed by Kolb (2005) was used in the research so as to identify the learning styles of pre-service mathematics teachers. There are 12 incomplete items in the inventory. Each of these items includes 4 options. For each situation, people are asked to give "4" points for the sentence which they think fits themselves the most, to give "3" points to the second fitting one, "2" points to the third fitting one and "1" point to the least fitting one. Each option indicates the expressions that show 4 learning preferences (concrete experience, reflective observation, abstract conceptualization and active experimentation). In this study, the reliability coefficients of the dimensions of the inventory were calculated as: concrete experience (0,72), reflective observation (0,76), abstract conceptualization (0,71) and active experimentation (0,72).

2.3. Data Analysis

Brain dominance of pre-service mathematics teachers was calculated through the points they got for each of the four-quadrant brain dominance in the inventory. At the end of the scoring conducted for 12 items in the learning style inventory, a minimum of 12 points and maximum of 48 points were earned in relation to each learning preference. Combined points used in identification of individual's learning style were calculated from this scoring. Combined points were obtained as abstract conceptualization (AC) - concrete experience (CE) (perceiving knowledge) and active experimentation (AE) - reflective observation (RO) (processing knowledge). AC-CE and AE-RO combined points vary between -36 and +36. The combined point obtained through AC-CE was placed on "y" axis while the combined point obtained through AE-RO was placed on "x" axis in the coordinate system given in Learning Style Type Grid (Version 3.1) and the area where the two points intersect was defined as the learning style (*diverger, assimilator, converger, accommodator)* of the individual (Kolb & Kolb, 2005).

Frequency, percentage and mean, which are among the descriptive statistics, were used in examining brain dominance and learning style profiles of pre-service teachers. One-way analysis of variance was used in determining whether there is a statistically significant difference in brain dominances according to learning styles and correlation analysis was used in examining whether there is a significant relation between learning style and brain dominances.

3. Findings

As a result of the data analysis, the findings on problem and sub-problems of the research are summarized under this heading. The first sub-problem involved determination of the profiles in learning styles and dimensions of learning styles of pre-service teachers. Data related to this problem are listed in Table 1.

Table 1. Descriptive statistical data on the learning styles and dimensions of learning styles of pre-service mathematics teachers

Learning Style	f	%	Dimensions	Mean	SD	Minimum	Maximum
Diverger	36	13,2	CE	22,80	4,95	13	42
Assimilator	98	35,9	RO	27,54	6,50	14	46
Converger	110	40,3	AC	35,62	5,29	18	48
Accommodator	29	10,6	AE	34,03	5,64	19	46
Total	273	100	AE-RO	6,48	10,58	-24	32
			AC-CE	12,82	8,30	-18	32

As is seen in Table 1, most of the pre-service teachers have converger (%40,3) learning style while least of them (%10,6) have accommodator learning style. Distribution of learning styles of pre-service teachers is converger, assimilator, diverger and accommodator respectively from the most common to the least common one. Given the descriptive statistics in dimensions of learning styles, it was seen that pre-service teachers attain the highest mean in AC dimension and the lowest mean in CE dimension. It is seen that they have a mean of M= 6,48 for AE – RO (in processing knowledge) and a mean of M= 12,82 for AC – CE (in perceiving knowledge) in combined scores.

For the second sub-problem, statistics for brain dominance analysis scores of pre-service teachers were obtained (see Table 2).

Table 2. Descriptive statistical data on the brain dominance analysis scores of pre-service mathematics teachers

Brain Quadrants	Mean	SD	Minimum	Maximum
A	20,14	2,78	13	27
B	20,97	3,35	11	29
C	23,87	2,82	11	30
D	21,65	2,61	12	28

The descriptive statistics for brain dominance analysis show that means of pre-service teachers are ranked as C (M=23,87), D (M=21,65), B (M=20,97) and A (M=20,14) quadrants respectively from the most to the least common.

Table 3 was reached when learning styles and brain dominance analysis of pre-service teachers were addressed together.

Table 3. Descriptive statistical data on the pre-service mathematics teachers' brain dominance analysis scores according to learning styles

	Diverger		Assimilator		Converger		Accommodator	
Brain Quadrants	Mean	SD	Mean	SD	Mean	SD	Mean	SD
A	19,36	3,26	19,84	2,92	20,73	2,44	19,86	2,58
B	19,72	4,15	20,46	3,53	21,68	2,89	21,51	2,59
C	23,63	3,53	23,20	2,94	24,39	2,54	24,44	1,88
D	21,41	3,34	21,44	2,49	21,60	2,49	22,89	2,16

By examining Table 3, we can see that the pre-service teachers whose brain dominance is in quadrant A and B have the highest mean in converger learning style and the lowest mean in diverger learning style while the pre-service teachers whose brain dominance is in quadrant C and D have the highest mean in accommodator learning style; the ones in quadrant C have the lowest mean in assimilator and the ones in quadrant D have the lowest mean in diverger learning style. In all learning styles, quadrant C has the highest and quadrant A has the lowest mean.

One-way analysis of variance was conducted for the purpose of being able to find an answer to the question of whether the brain dominance analysis scores of pre-service teachers, which is the fourth sub-problem of the research, create a significant difference according to learning styles. The findings obtained as a result of the analysis were organized by Table 4.

Table 4. The ANOVA results on the pre-service mathematics teachers' brain dominance analysis scores according to their learning styles

Brain Quadrants	Source of Variance	Sum of Squares	df	Mean Square	F	p	Sig.
A	Between Groups	71,616	3	23,872	3,151	,025*	Diverger-Converger
	Within Groups	2037,812	269	7,576			
	Total	2109,429	272				
B	Between Groups	145,030	3	48,343	4,455	,004*	Diverger-Converger Assimilator-Converger
	Within Groups	2918,735	269	10,850			
	Total	3063,766	272				
C	Between Groups	84,926	3	28,309	3,662	,013*	Assimilator-Converger
	Within Groups	2079,587	269	7,731			
	Total	2164,513	272				
D	Between Groups	51,234	3	17,078	2,544	,057	-
	Within Groups	1806,085	269	6,714			
	Total	1857,319	272				

As is seen in Table 4, brain dominance analysis scores of pre-service teachers who are in A, B and C brain quadrants differ significantly according to learning styles. Multiple comparisons were made in order to determine among which groups the significant difference is. It was observed in the comparison that there is significant difference between the diverger - converger learning styles of brain dominance analysis scores of pre-service teachers in the A brain quadrant; diverger - converger and assimilator - converger learning styles of pre-service teachers in B brain quadrant and assimilator - converger learning styles of pre-service teachers in C brain quadrant. The means of pre-service teachers who have converger learning styles in A, B and C quadrants are higher. Brain dominance analysis scores of pre-service teachers in D brain quadrant did not show any difference according to learning styles.

The correlation coefficients between learning style dimensions and brain dominance analysis scores of pre-service teachers were investigated in order to search for a solution to the final sub-problem of the research (see Table 5).

Table 5. Correlation coefficients between pre-service mathematics teachers' learning style dimensions and brain dominance analysis scores

Dimensions / Quadrants		CE	RO	AC	AE	AE-RO	AC-CE
A	r	,014	-,146*	,079	,081	,133*	,043
	sig.	,824	,016	,191	,183	,029	,484
B	r	-,053	-,159**	,136*	,102	,152*	,118
	sig.	,383	,008	,024	,094	,012	,051
C	r	,055	-,140*	,034	,081	,129*	-,011
	sig.	,366	,020	,580	,184	,033	,852
D	r	,132*	-,126*	-,003	,031	,094	-,080
	sig.	,030	,038	,965	,611	,122	,186

**:p<,01; *:p<,05

The correlation coefficients in Table 5 show that there are statistically significant relations at the level of 95% between A brain quadrant of pre-service teachers and reflective observation and AE-RO (processing knowledge); between B brain quadrant and abstract conceptualization and AE-RO (processing knowledge); between C brain quadrant and reflective observation and AE-RO (processing knowledge) and between D brain quadrant and concrete experience and reflective observation. All these relations mentioned are low. Statistically significant relation at the level of 99% is only available between B brain quadrant and reflective observation and this relation is negative and at low level.

4. Discussion and Conclusion

This research aimed to determine brain dominance and learning style profiles of pre-service mathematics teachers and to reveal the relations between them.

According to the results obtained from Kolb's learning style inventory, pre-service teachers prefer learning through "abstract conceptualization" in perceiving knowledge and "active experimentation" in processing knowledge more. It can be suggested according to the findings acquired that pre-service teachers prefer thinking to feeling in perceiving knowledge and doing-applying to watching in processing knowledge. It was also discovered that knowledge perceiving scores of pre-service teachers are lower than their knowledge processing scores. By and large, when knowledge perceiving and knowledge processing scores and learning styles of pre-service teachers are examined, it is seen that they prefer converger, assimilator, diverger and accommodator learning respectively from the most to the least common. Similar findings are also acquired in studies conducted in order to determine learning styles of pre-service mathematics teachers (Küçükkaragöz et al., 2009; Orhun, 2007; Peker, Mirasyedioğlu & Aydın, 2004; Peker, 2009). In the previous researches, the most preferred learning style is given as assimilator and converger while the least preferred one is given as accommodator and diverger.

The results obtained through brain dominance analysis inventory demonstrated that "C" and "D" brain quadrants were more dominant in pre-service mathematics teachers. This shows that pre-service teachers are inclined to use the mental preferences in quadrants C and D more. This finding does not imply that there are no mental preferences in quadrants A and B. It is indicated by various researches that mostly left brains of people dealing with the field of mathematics, mathematicians or people successful in mathematics are dominant (Ali & Kor, 2007; Herrmann, 2003; Leng et al., 1998; Steyn & Maree, 2002). However, it is observed in this research that right hemisphere quadrants of pre-service teachers are more dominant. The resulting situation is in compliance with the fact that teachers have more dominant mental preferences especially in quadrant C according to the researches conducted by Herrmann (2003). This mental preferences (the fact that their C and D brain preferences are more dominant) of pre-service teachers can be found natural as they will be future teachers.

According to research findings, the pre-service teachers who are dominant in brain quadrants A and B have the highest mean in converger learning style; the pre-service teachers who are dominant in brain quadrants C and D have the highest mean in accommodator learning style. The pre-service teachers who are dominant in brain quadrants A, B and D have the lowest mean in diverger learning style while the pre-service teachers who are dominant in brain quadrant C have the lowest mean in assimilator learning style. Quadrant C seems to have the highest score and quadrant A seems to have the lowest score in all learning styles. Statistically significant differences were found in quadrants A, B, C in brain dominance analysis scores in terms of learning styles. A similar situation is also emphasized in the previous studies (Ali & Kor, 2007; Seng &Yeo, 2000).

It cannot be said that the view that people whose left brain preference is dominant are more successful in the process of mathematics learning reflects the reality exactly. For instance, solving mathematical problems require exhibition of both intuitive and logical approaches (Kitchens, Barber & Barber, 1991; Leng et al., 1998). Acknowledging the fact that the learning process occurs through mental activities based on left, right and the whole brain is the most accurate approach. People naturally carry out mental activities in different ways and have learning preferences accordingly. The important thing is to embrace these differences in the process of learning and to reflect the correct approach in the process. It is asserted that carrying out analytical and logical mental activities in mathematics classes intensively limits creative, imaginative and social mental activities of students (Kitchens, Barber & Barber, 1991; Özden, 2009). Mathematics education based on left brain obstructs students with dominant right brains and keeps their success at low level.

Regardless of their own brain dominances and learning style profiles, teachers should be sensitive to learning requirements of students with different structures depending on these individual differences in the classroom. Providing opportunity for students to use their brain hemispheres together facilitates making mathematics learning based on whole brain more effective and flexible. Mathematics teachers should select the most effective teaching strategies in using a framework which will affect learning based on the differences between brain dominances and learning styles of their students. In the researches to be conducted in the future, brain dominances and learning style profiles of students at different age groups in the mathematics learning process should be examined more comprehensively and the relations between them should be tried to be illuminated because the researches for establishing the process of mathematics learning by taking the differences in brain dominance and learning styles into account as well as designing and implementing the learning process, environment and materials can present useful findings.

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